(321) EG-2

MSC INTERNAL NOTE NO. EG-67-19

PROJECT APOLLO

LUNAR MODULE REDESIGNATION FOOTPRINT CAPABILITY DURING FINAL APPROACH

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Houston, Texas
June 12, 1967

SUMMARY

A method of determining the additional delta V required for landing point redesignations during the LM powered descent has been developed. An analysis of the problem, description of the general purpose computer program, and selected footprint contours from various redesignation altitudes are included in the report.

INTRODUCTION

A considerable interest has been expressed concerning the capability of the LM to redesignate to a new landing point using the Landing Point Designator (LPD). A previous analysis examined the footprint capability of the LM for various expenditures of characteristic velocity (ref 1). This analysis, however, did not consider the effects of LPD operation as governed by the quadratic guidance equations used in the LM. To update the results of reference 1 the Guidance and Control Division has developed a quick yet explicit means for computing the additional characteristic velocity required for discrete redesignations based on the LM guidance equations at instantaneous state vector conditions extracted from a predefined descent trajectory.

ANALYSIS

In order to evaluate the additional characteristic velocity required for LPD landing point redesignations, it was necessary to construct a mathematical model which, using a predefined nominal trajectory, would compute the additional ΔV required for various combinations of $\frac{1}{2}^{o}$ downrange and 2^{o} crossrange redesignation. The analytic technique involved in the study required nominal LM state vector data at desired points of evaluation (in this case, at discrete altitudes). The state vector data included the present, and desired terminal: displacement, velocity, and acceleration; terminal jerk; and the extrema of downrange and uprange (long and short) angular redesignations. The lateral or crossrange redesignations were allowed to increment from 0^{o} in steps of 2^{o} until the terminal yaw angle (ψ_f) exceeded 90^{o} (ref 2). The method used first solved for a new time-to-go to the terminus of the phase corresponding to the particular redesignation involved. The coefficients of the quadratic, commanded acceleration equations (ref 3 and 4) were next computed. Without further redesignation the LM would descent to the terminus of the final approach phase along a trajectory governed by the quadratic acceleration equations as defined by the last set of computed coefficients. Because of the relatively small displacements involved, a flat lunar surface was

assumed. The characteristic velocity change (ΔV) was defined in terms of acceleration as

$$\Delta V = \int_0^{T_{go}} \left| \bar{a}_{Th} \right| dt$$

where:

T_{go} = time-to-go to the terminus of the phase

$\bar{a}_{Th}$ = thrust acceleration vector

(Note: In a vacuum, $\bar{a}_{Total} = \bar{a}_{Th} + \bar{g}$; where $\bar{g}$ = local gravitational acceleration vector)

The difference between the ΔV to the nominal terminus of the phase and the ΔV corresponding to the different redesignations $\Delta(\Delta V)$ were interpolated to arrive at the various displacements corresponding to the desired 90, 60, 30, and 0 ft/sec ΔV contours (each representing a fractional part of the nominally budgeted 90 ft/sec).

RESULTS

The results of the analysis have been plotted in figures 1-5 which show the LPD redesignation capability from five separate redesignation altitudes as a function of additional delta V expended.

CONCLUDING REMARKS

The footprint contours of this report are free of such operational constraints as window visibility, attitude, and descent engine thrust limitations. For this reason, the figures may show somewhat more footprint capability than exists for an actual delta V expenditure of the LM. However, because the data contained in this report includes the effect of the quadratic guidance, it should be used to supersede the corresponding footprint information of reference 1.

REFERENCES

1. Moore, Thomas E.: An Analytical Study of the Landing Footprint Available During LEM Lunar Landing Approaches. NASA Project Apollo Working Paper No. 1106, January 1964.

2. "Terminal LM Yaw Angle for LM LPD Lateral Redesignations," NASA MSC Memorandum EG27-67-50.

3. Klumpp, Allen R.: A Manually Retargeted Automatic Descent and Landing System for LEM. MIT/IL Report R-539, March 1966.

4. Cherry, George W.: E Guidance-A General Explicity, Optimizing Guidance Law for Rocket-Propelled Spacecraft. MIT/IL Report R-456, August, 1964.

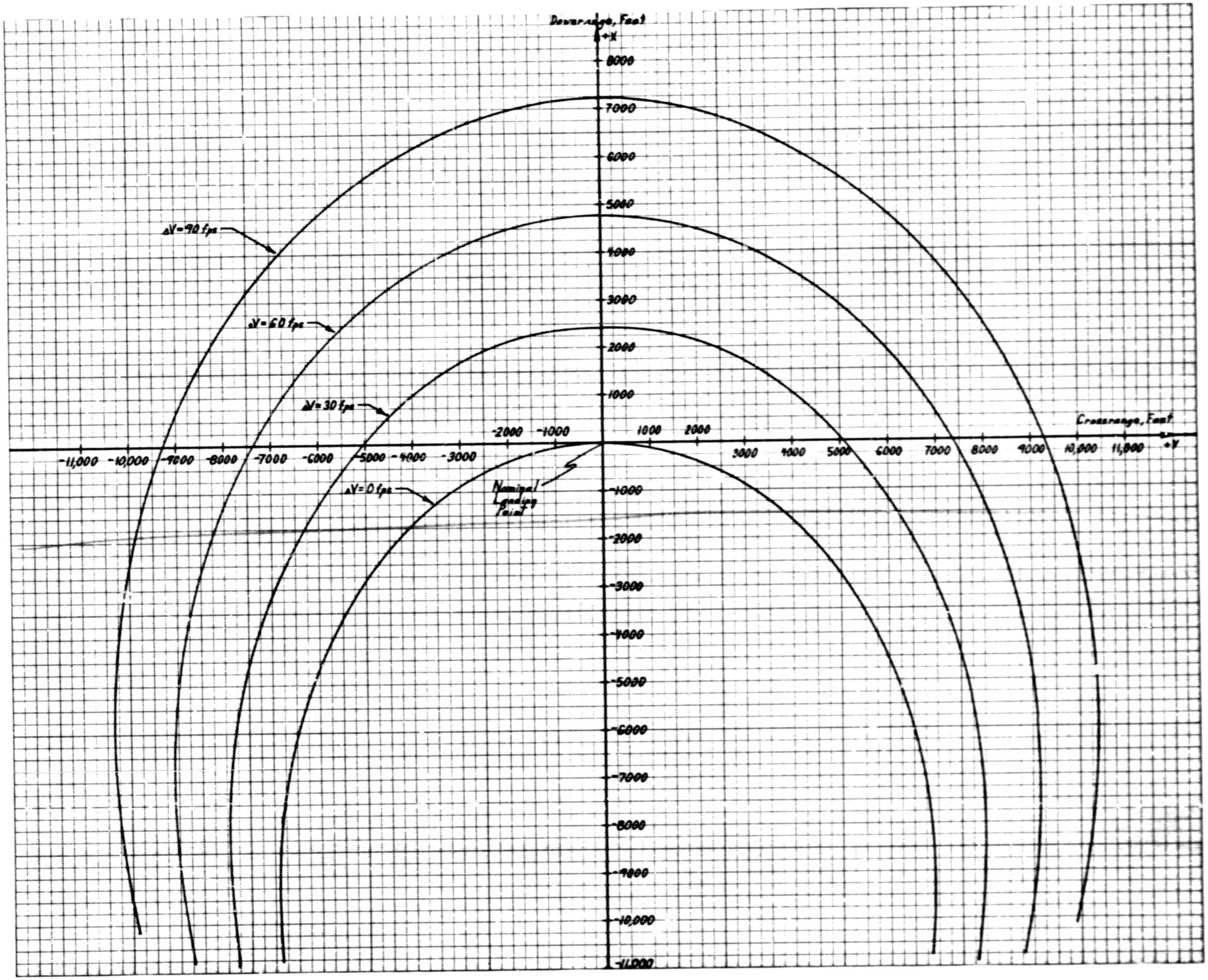

Figure 1.- LM REDESIGNATION FOOTPRINT CAPABILITY
LM Position ~ Altitude = 7,000 ft.
Range 25,569 ft.

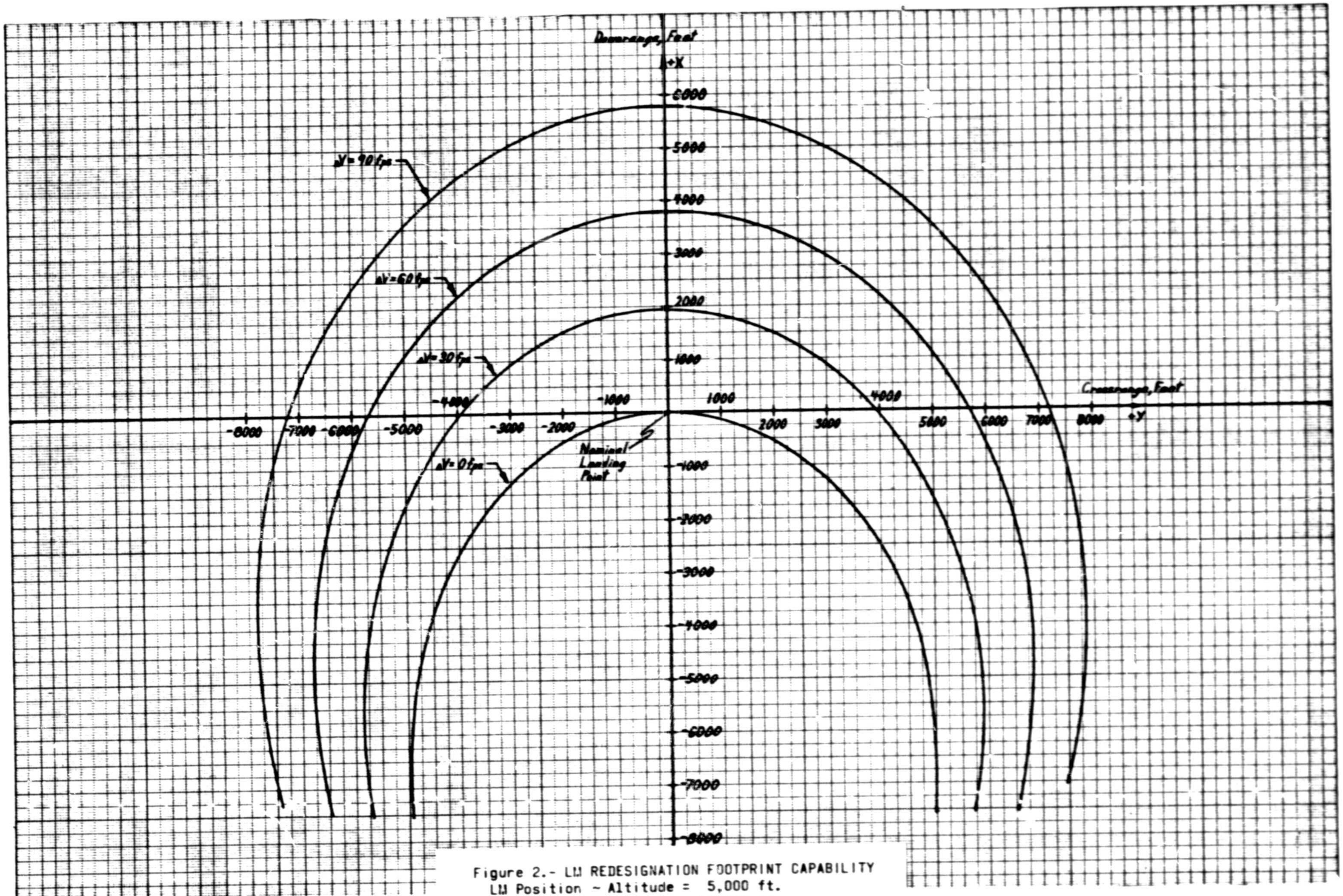

Figure 2.- LM REDESIGNATION FOOTPRINT CAPABILITY
LM Position ~ Altitude = 5,000 ft.
Range = 18,042 ft.

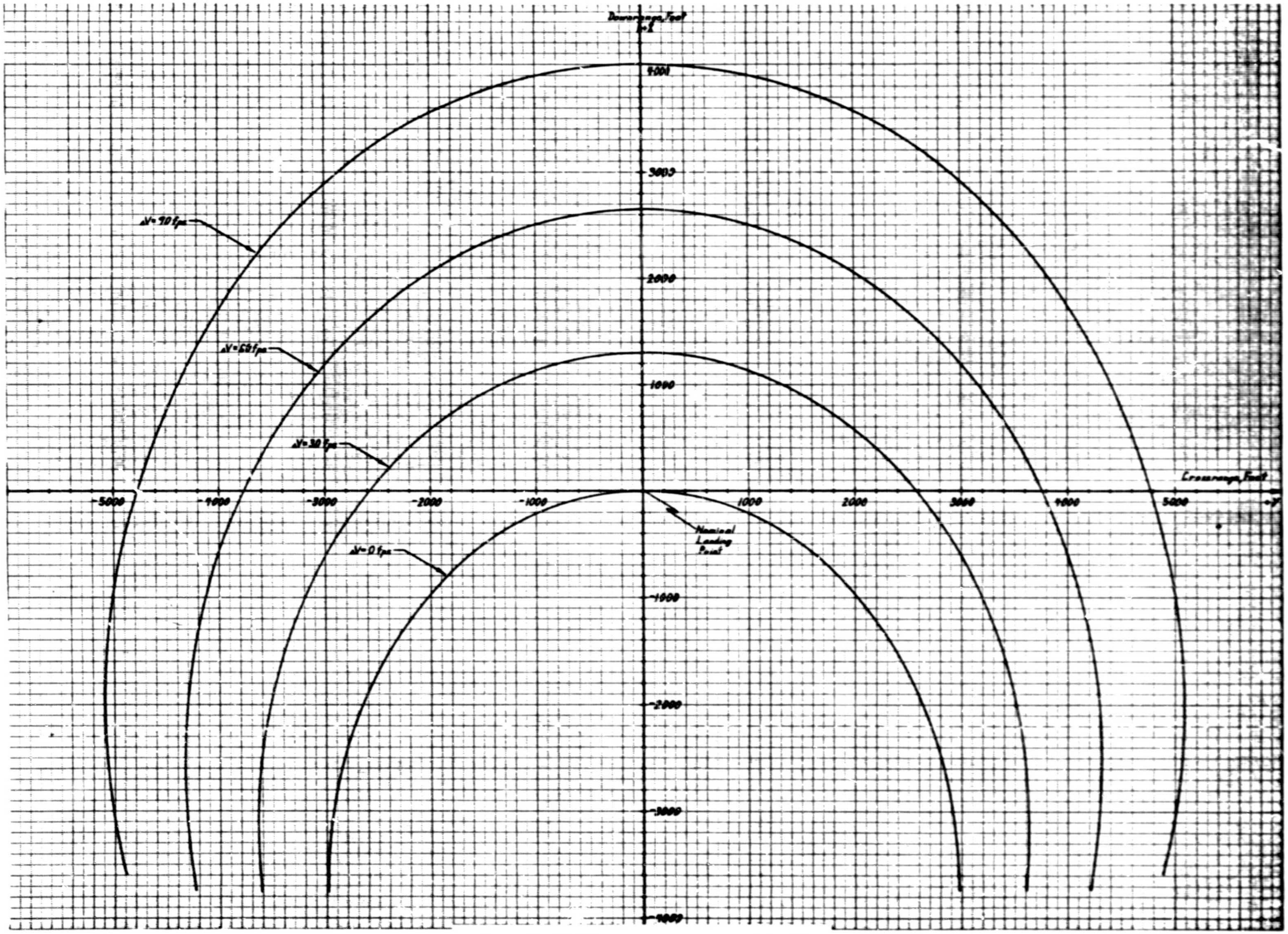

Figure 3.- LM REDESIGNATION FOOTPRINT CAPABILITY
LM Position - Altitude = 3,000 ft.
Range = 10,237 ft.

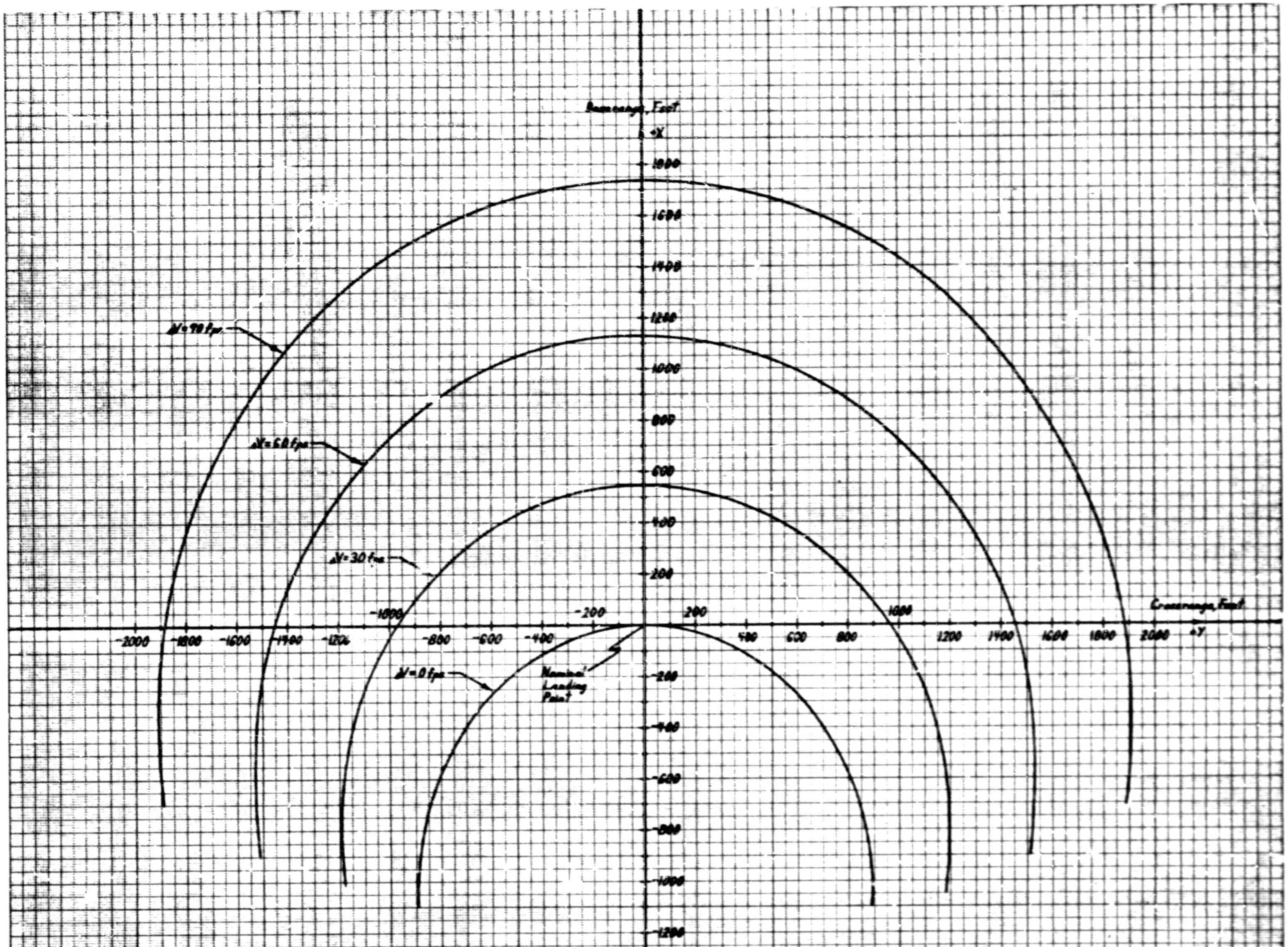

Figure 4.- LM REDESIGNATION FOOTPRINT CAPABILITY
LM Position ~ Altitude = 1,000 ft.
Range = 2,648 ft.

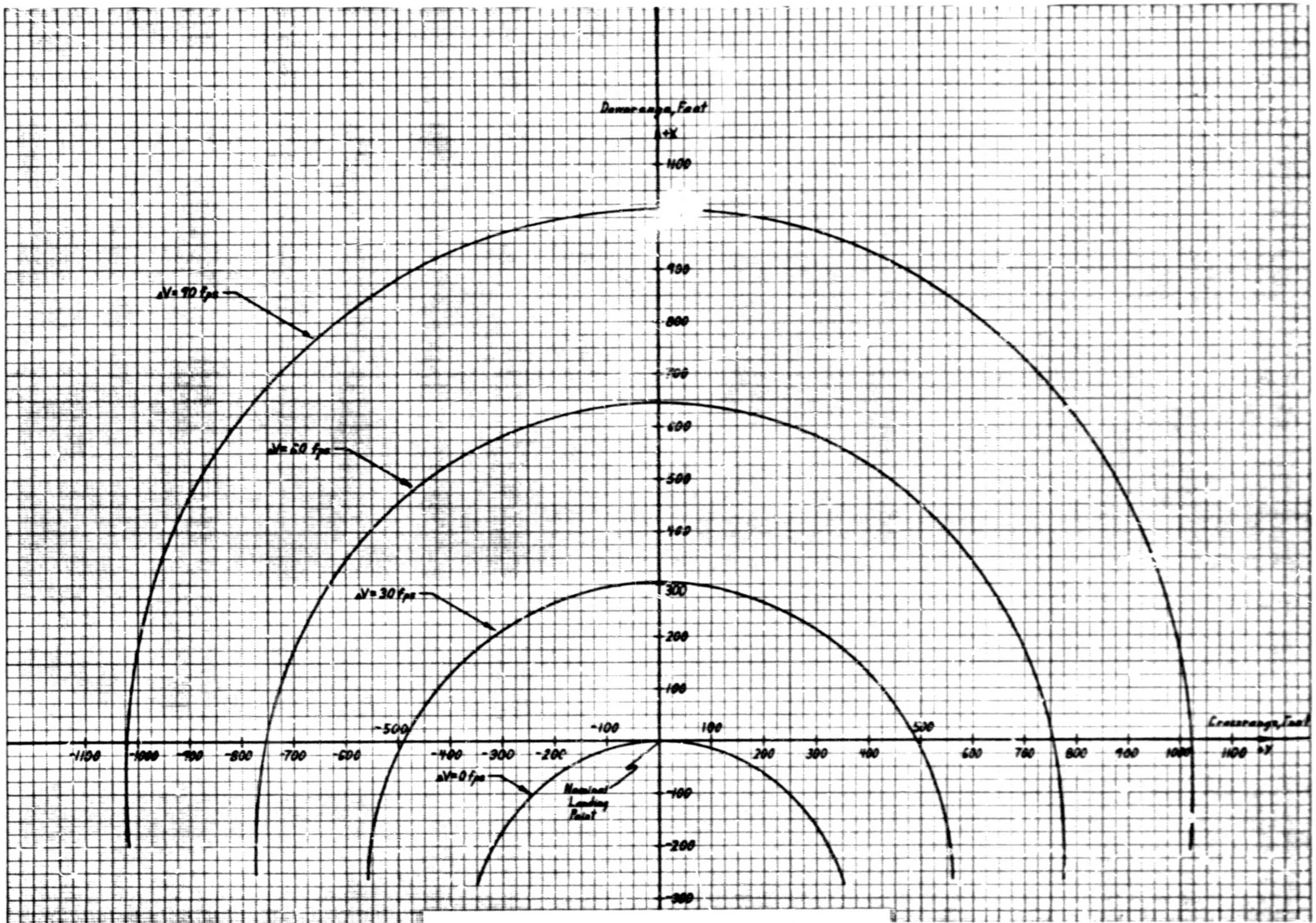

Figure 5.- LM REDESIGNATION FOOTPRINT CAPABILITY
LM Position ~ Altitude = 500 ft.
Range = 1,010 ft.